On the Assimilation of Polarimetry-Derived Hydrometeor Mixing Ratios in Germany

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DWD Radar Network and Retrievals

LWC(Z,ZDR,A,KDP)
of Reimann et al. (2021):

$$LWC(Z, Z_{DR}) \quad for \quad \Delta\Phi_{DP} < 5\,deg,$$

$$LWC(A) \quad for \quad \Delta\Phi_{DP} \geq 5\,deg \quad and \quad Z < 45\,dBZ,$$

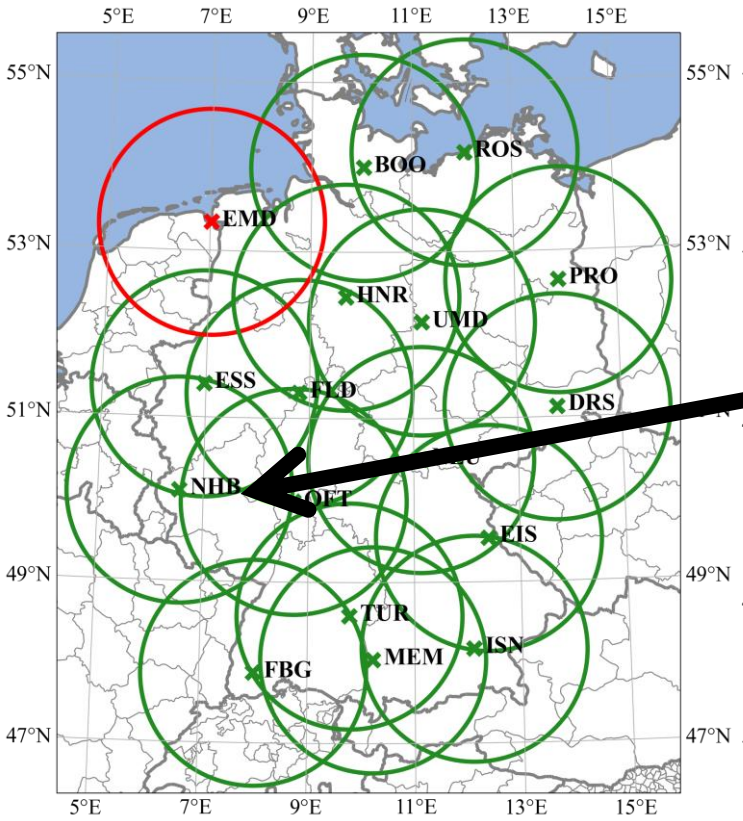
and

$$LWC(K_{DP}) \quad for \quad \Delta\Phi_{DP} \geq 5\,deg \quad and \quad Z \geq 45\,dBZ.$$

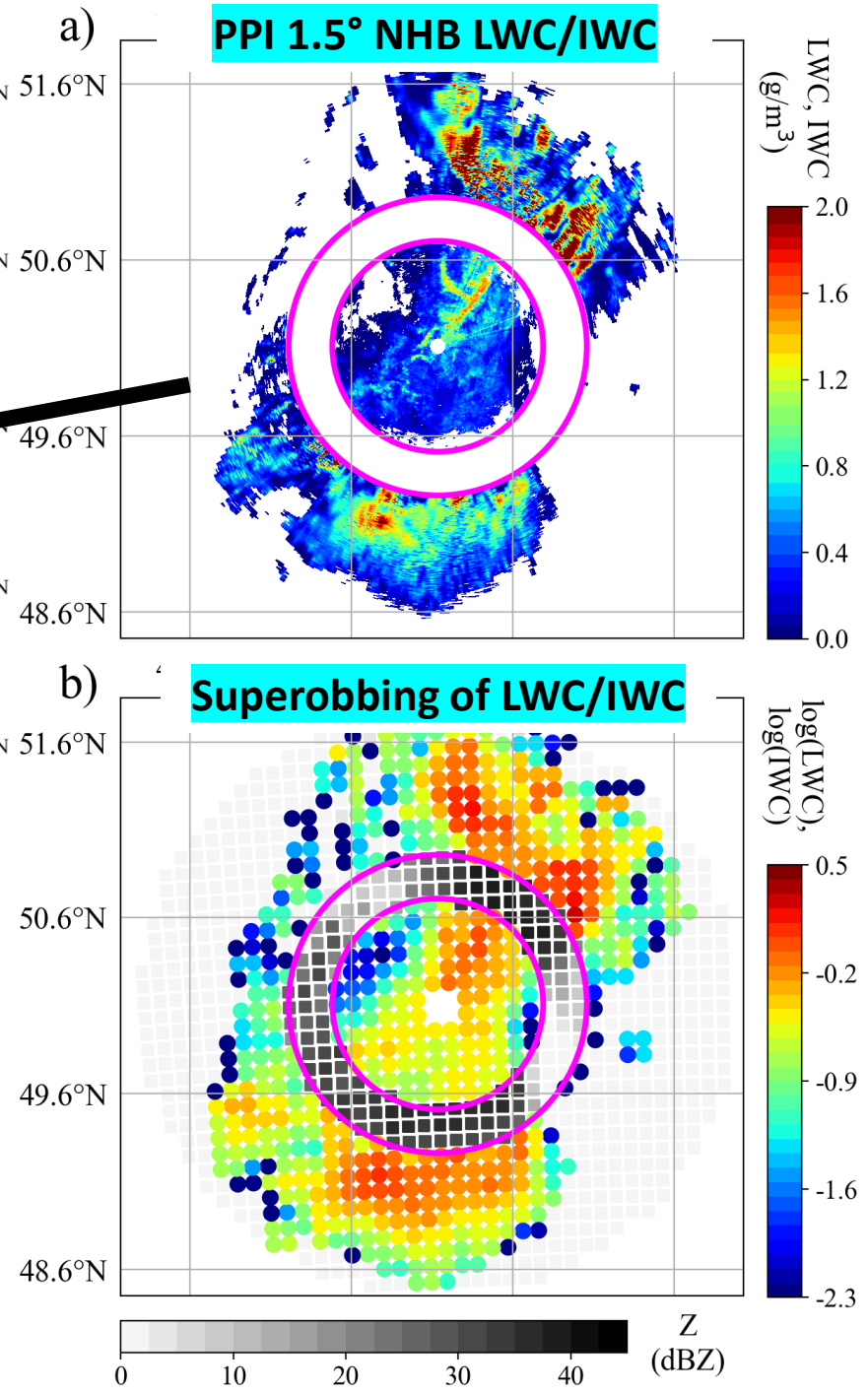
IWC(Z,ZDR,KDP)
of Carlin et al. (2021):

$$IWC(K_{DP}, z_{DR}) = 4.0 * 10^{-3} \frac{K_{DP}\lambda}{1 - z_{DR}^{-1}} \quad \text{if ZDR>0.4dB}$$

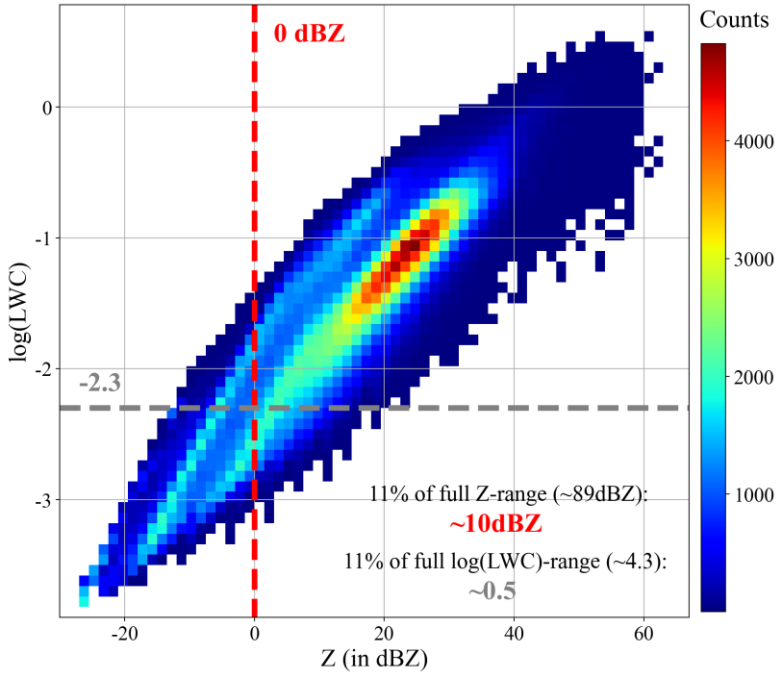
$$IWC(K_{DP}, z) = 3.3 * 10^{-2} (K_{DP}\lambda)^{0.67} z^{0.33} \quad \text{if ZDR<0.4dB}$$



Assimilation of 3D LWC/IWC:
5 elevation angles
1.5, 3.5, 5.5, 8.0, 12.0 degrees



3D Retrieval Assimilation Settings



Test DAP settings w.r.t. first-guess (hourly) QPF quality (**FSS** & **BSS**) in hourly assimilation cycles with configurations:

CNV+LWC/Z

Conventional data + 3D LWC instead of Z where possible

CNV+Z

Conventional data + 3D Z

CNV+IWC/Z

Conventional data + 3D IWC instead of Z where possible

DAP values	LH (km)	LV (ln(p))	OE	LS (km)	LL	MV
Pre-selected (setting S-pre)	16	h.d.	0.50	10	-2.30	3
Variation 1	8	0.2	0.25	5	-1.15	25%
Variation 2	32	0.5	1.00	20	-4.60	50%

DAP Settings	LH (km)	LV (ln(p))	OE	LS (km)	LL	MV
S1-01	16	h.d.	1.00	5	-2.30	50%
S1-02	8	0.5	0.25	10	-1.15	50%
S1-03	8	0.5	0.25	20	-1.15	3
S1-04	32	0.5	0.50	5	-2.30	25%
S1-05	8	0.2	0.25	10	-4.60	50%
S1-06	16	h.d.	0.50	20	-1.15	25%
S1-07	32	0.2	1.00	5	-1.15	3
S1-08	8	0.2	0.50	20	-2.30	3
S1-09	32	0.5	0.50	5	-4.60	25%
S1-10	16	h.d.	1.00	10	-4.60	25%
S1-11	32	h.d.	1.00	20	-4.60	3
S1-12	16	0.2	0.25	10	-2.30	50%
S2-01	16	0.2	1.00	20	-1.15	50%
S2-02	16	0.2	0.25	10	-2.30	3
S2-03	8	h.d.	1.00	20	-1.15	3
S2-04	16	0.2	1.00	20	-2.30	50%
S2-05	16	h.d.	0.25	10	-2.30	50%
S2-06	8	0.2	0.25	20	-1.15	3
S2-07	8	0.2	1.00	10	-1.15	3
S2-08	8	h.d.	0.25	10	-1.15	50%
S2-09	8	h.d.	1.00	20	-2.30	50%
S2-10	16	h.d.	0.25	10	-2.30	3

DAP: Data Assimilation Parameter

Assimilation Impact on First-Guesses

Precipitation test cases:

- C2017: 1.5-day convective precipitation in July 2017
- S2017: 3-day stratiform precipitation in July 2017
- S2021: 2-day stratiform precip. in July 2021 (Ahr flood)

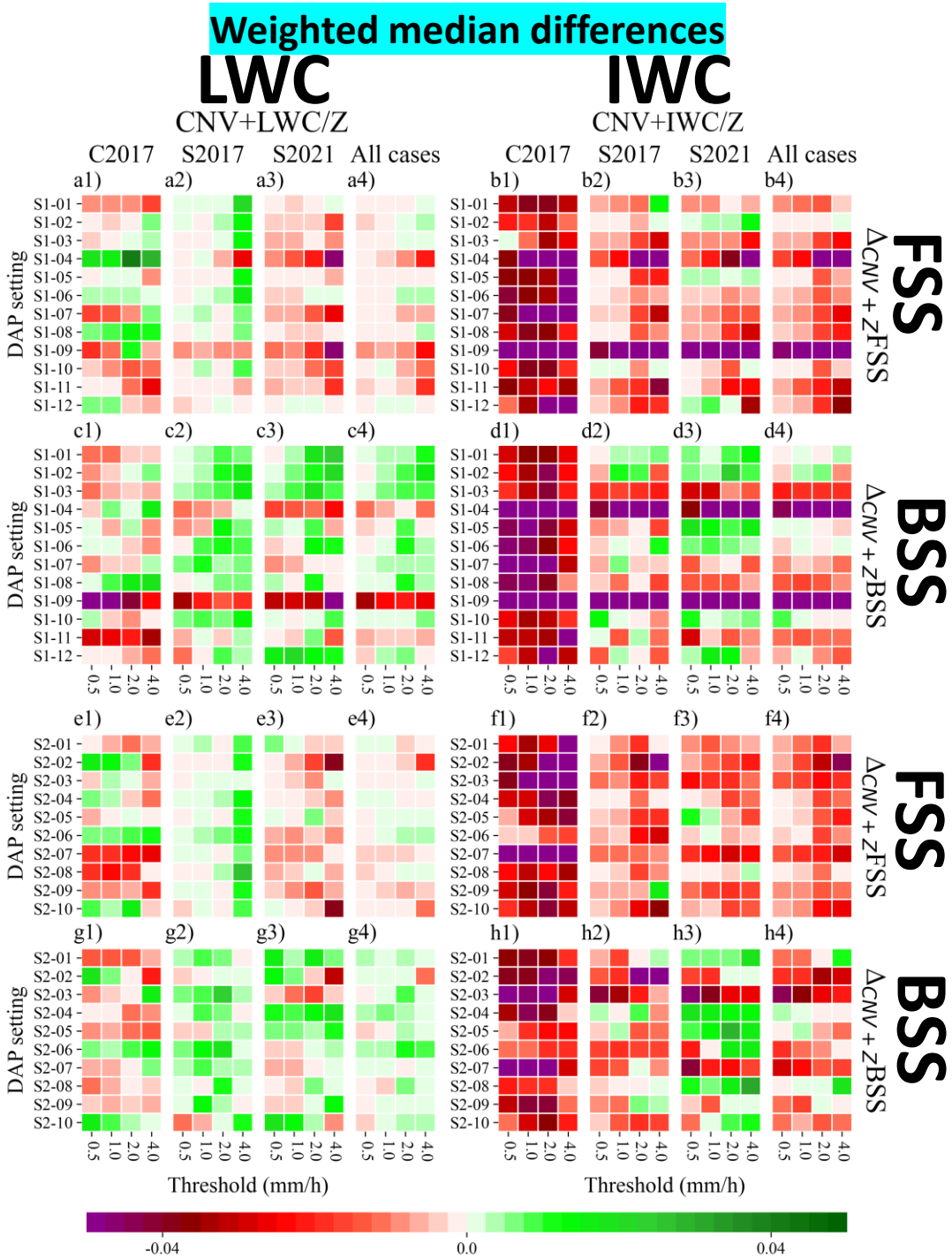
RADOLAN "RW"-product (hourly accumulations) used as verification data for FSS and BSS

Findings:

- LWC/IWC assimilation with different DAP settings leads to different first-guess quality
- LWC assimilation leads to more improvements over CNV+Z than IWC assimilation overall (more green colors)
- IWC assimilation mostly leads to first guess degradation for the convective case (C2017), but to improvements especially for the S2021 stratiform case

Possible reasons:

- IWC retrieval adjusted to snowfall, not to hail graupel likely occurring in convective precipitation
- IWC retrieval benefits from higher radial resolution for 2021 case (0.25 km) through improved KDP estimation

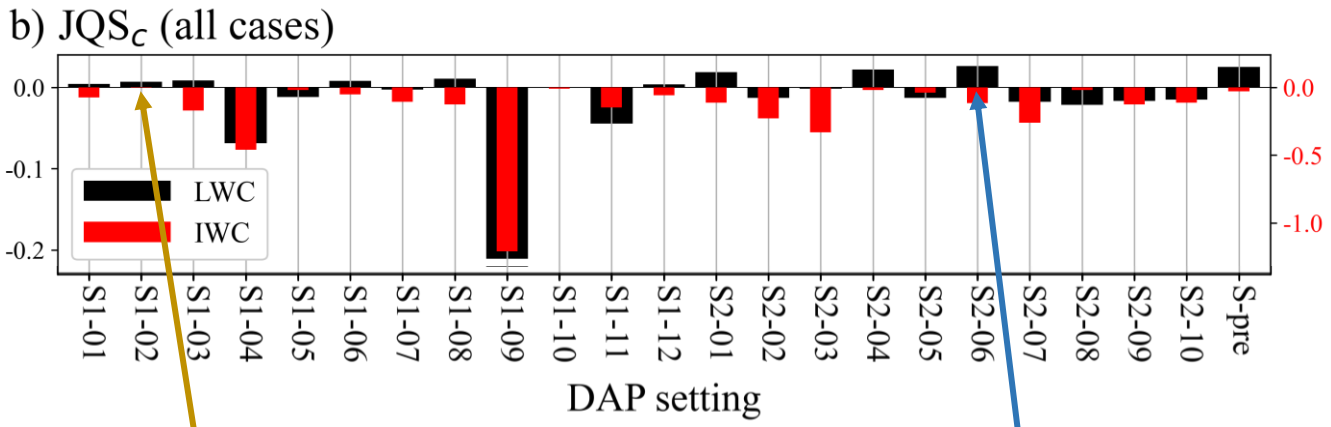


Assimilation Impact on First-Guesses

Introduction of "Joint Quality Score" (JQS) for decision making:

$$JQS_c = median_w\left(\Delta_{CNV+Z}FSS_{norm}[CNV+\cdot:/Z]\right) + median_w\left(\Delta_{CNV+Z}BSS_{norm}[CNV+\cdot:/Z]\right)$$

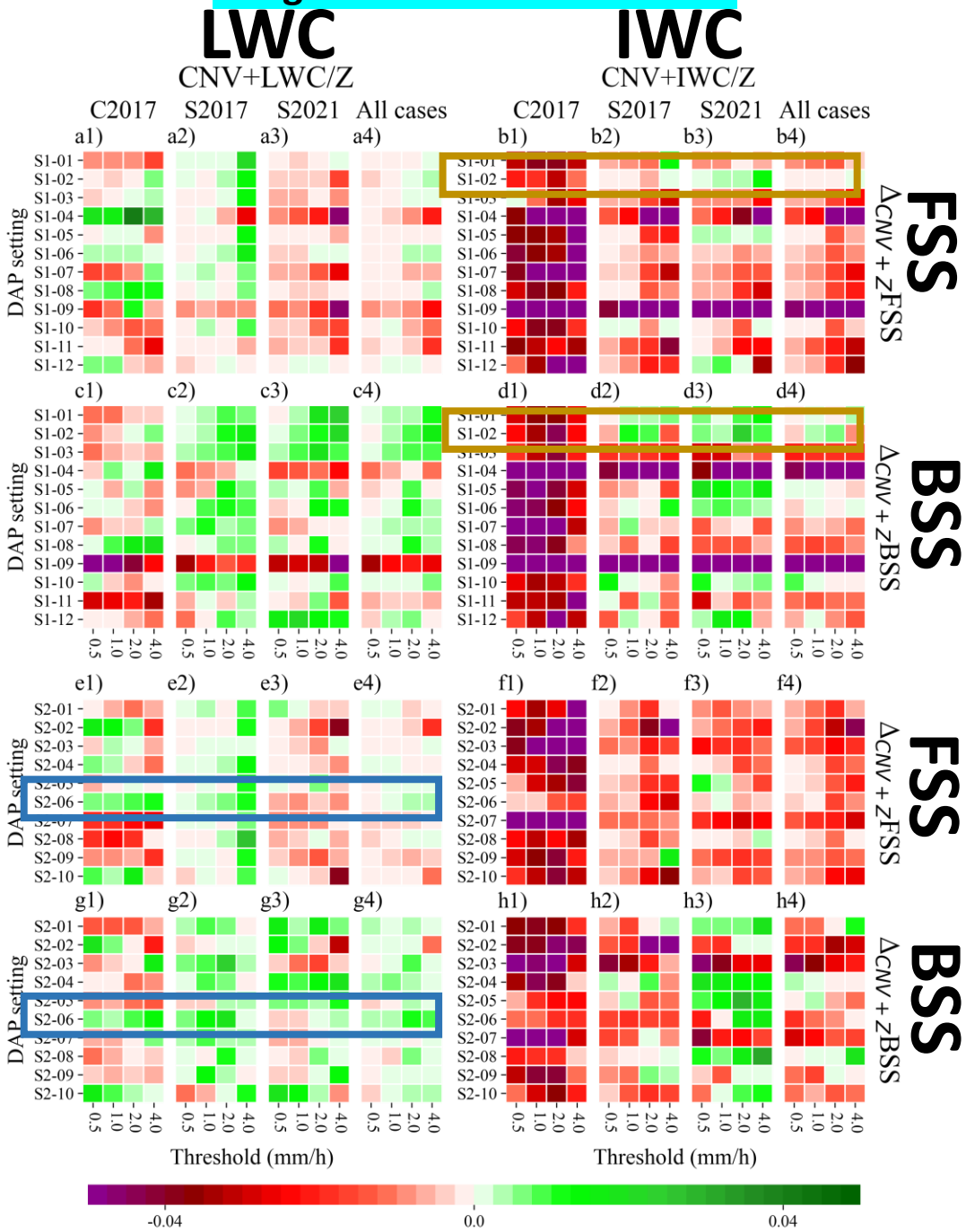
- *Weighted medians of FSS/BSS differences over all accumulation thresholds (0.5, 1.0, 2.0, 4.0 mm/h) and test cases (C2017, S2017, S2021)*
- *Weights: determined from number of threshold exceedances in RADOLAN*
- *Positive/negative JQS: deterministic and ensemble first guesses improved/degraded on median w.r.t. CNV+Z configuration*



Optimal DAP setting for IWC

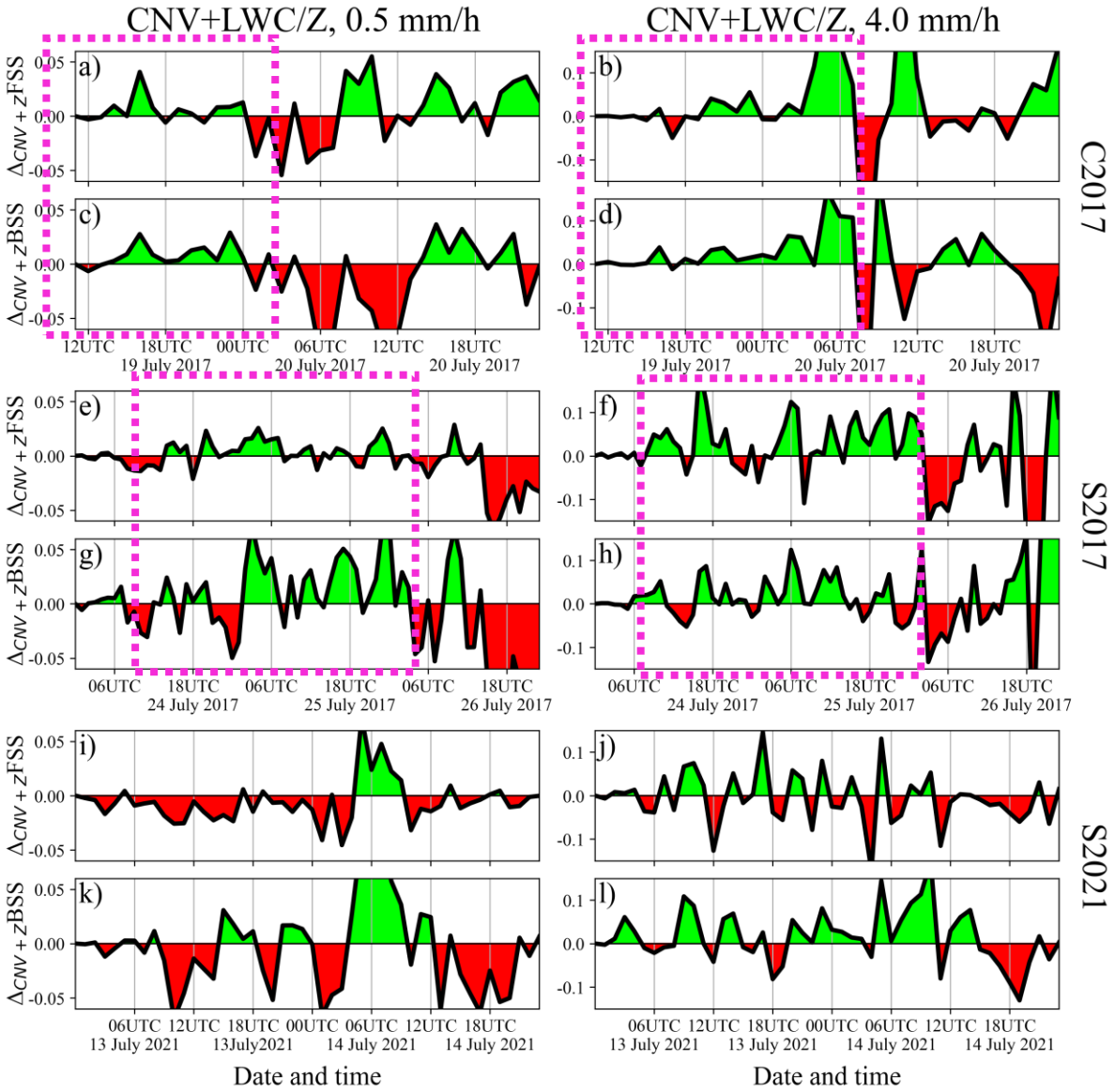
Optimal DAP setting for LWC

Weighted median differences

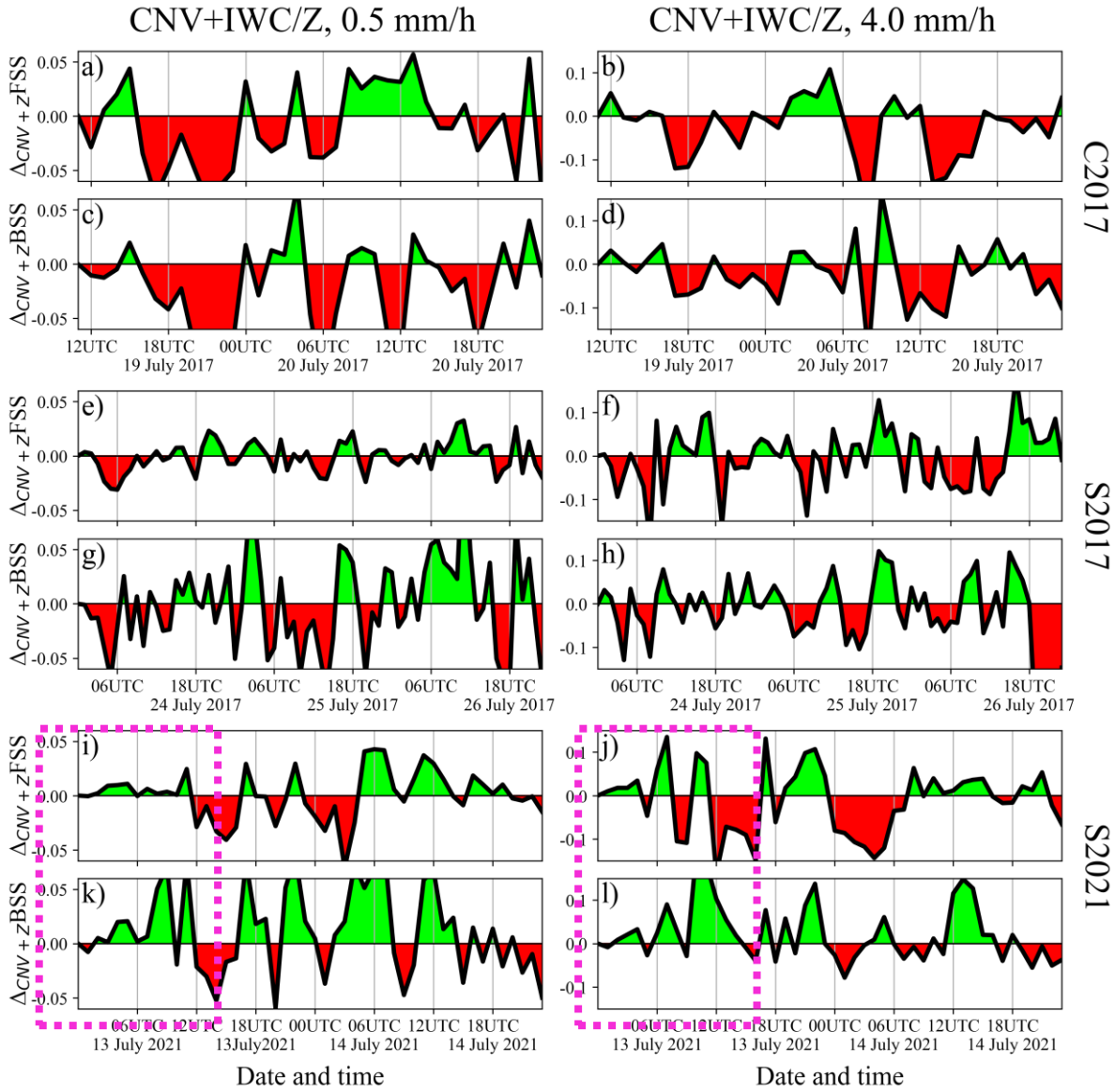


Assimilation Impact on First-Guesses

LWC assimilation with optimal DAPs

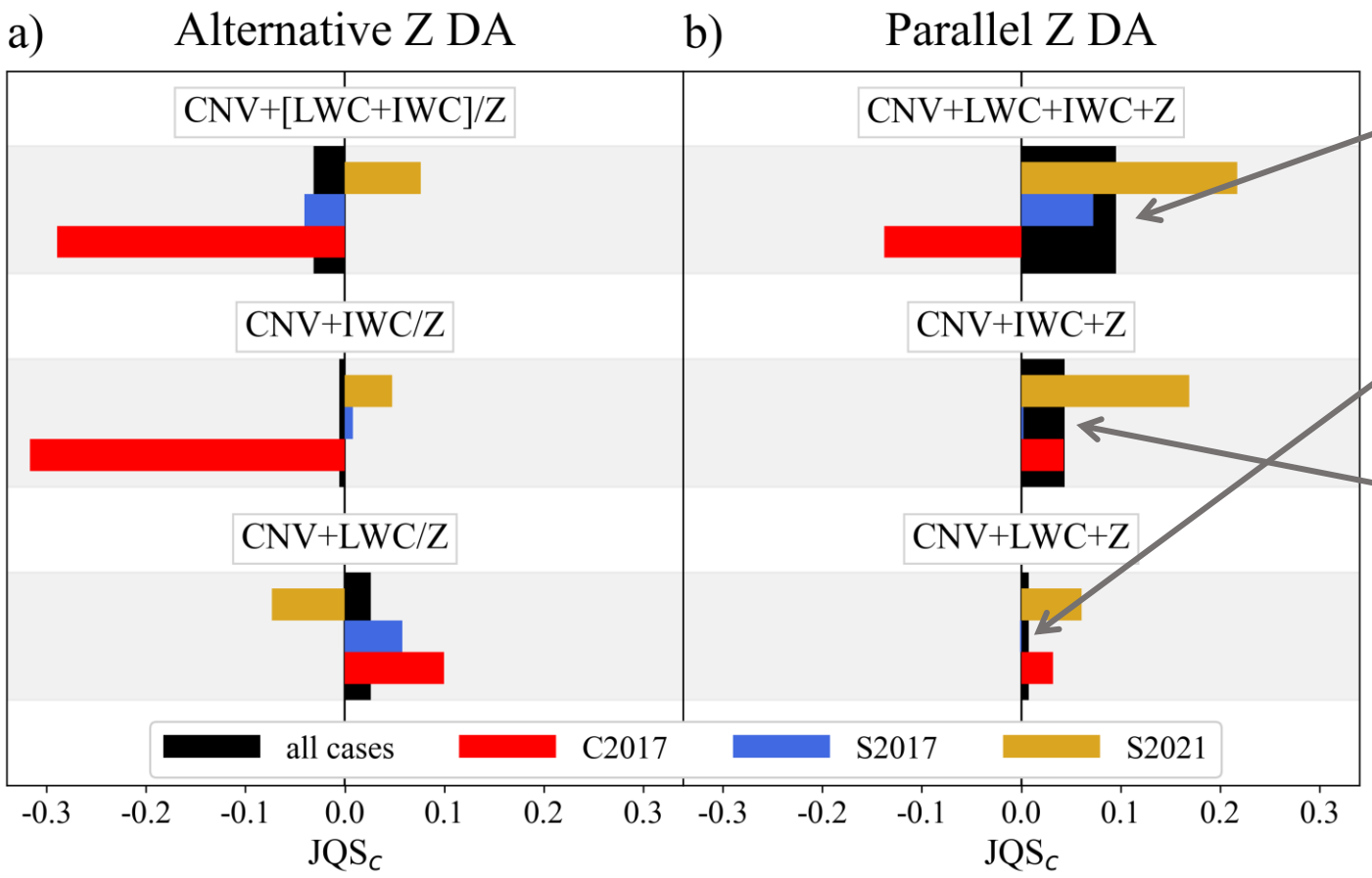


IWC assimilation with optimal DAPs



Assimilation Impact on First-Guesses

Test different radar data set combinations



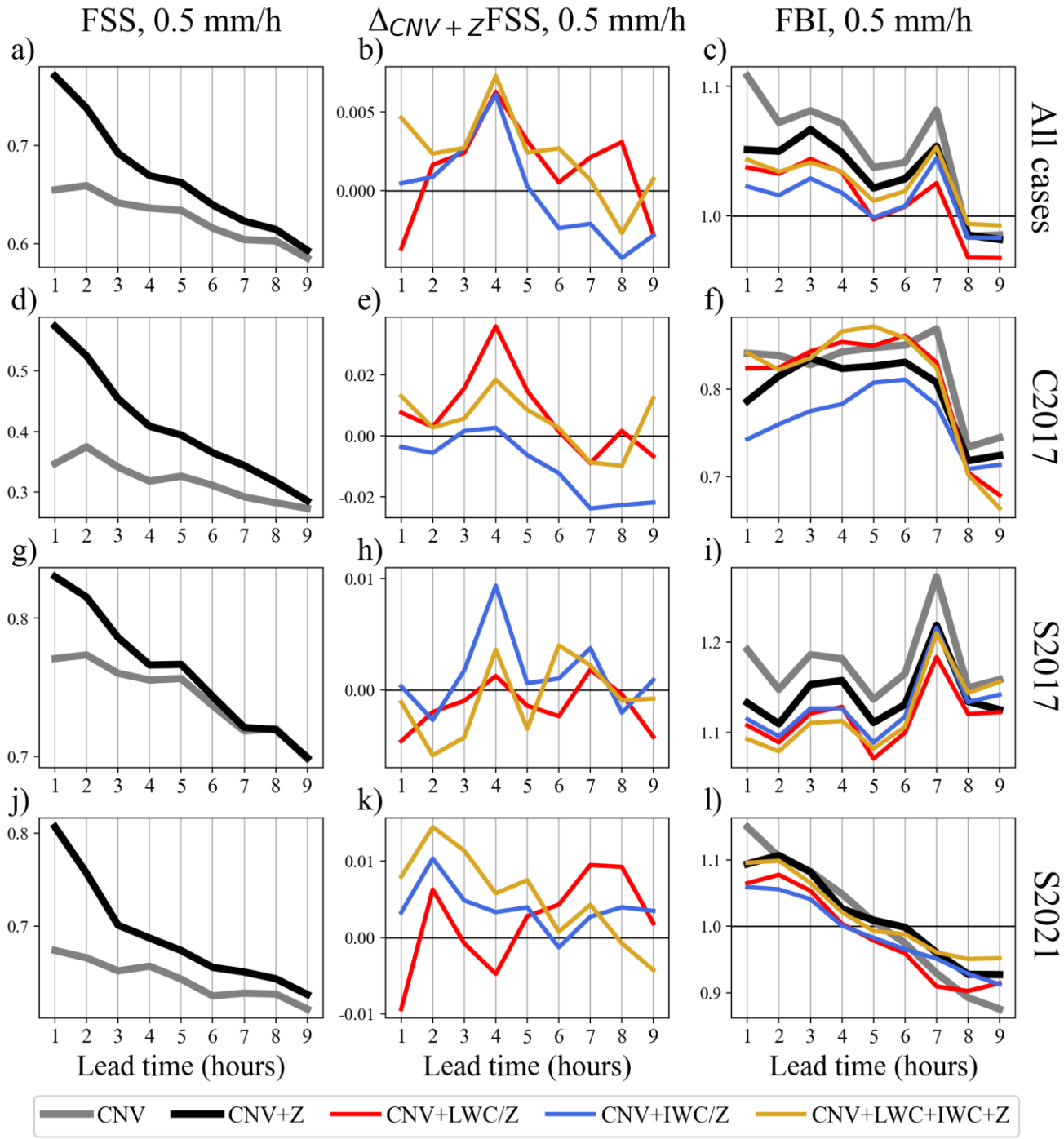
Findings:

- Assimilation of all radar data sets together (CNV+LWC+IWC+Z) results in best JQSc over all cases (black bars)
- Assimilating Z in parallel to LWC in CNV+LWC+Z degrades QPF quality w.r.t. alternative approach CNV+LWC/Z
- However, assimilating Z in parallel to IWC in CNV+IWC+Z improves first-guess quality w.r.t. alternative approach CNV+IWC/Z

Assimilation Impact on Nine-Hours Forecasts

Findings:

- LWC assimilation in CNV+LWC/Z leads to FSS improvements over CNV+Z, especially for C2017
- IWC assimilation in CNV+IWC/Z leads to FSS improvements, especially for S2021, while C2017 is less successful (as expected)
- Assimilation of all radar data sets in CNV+LWC+IWC+Z results in best FSS for the first 6 hours lead time overall and for the S2021 case
- All LWC/IWC configurations improve det. FBI on mean over all cases



Conclusions

First guesses

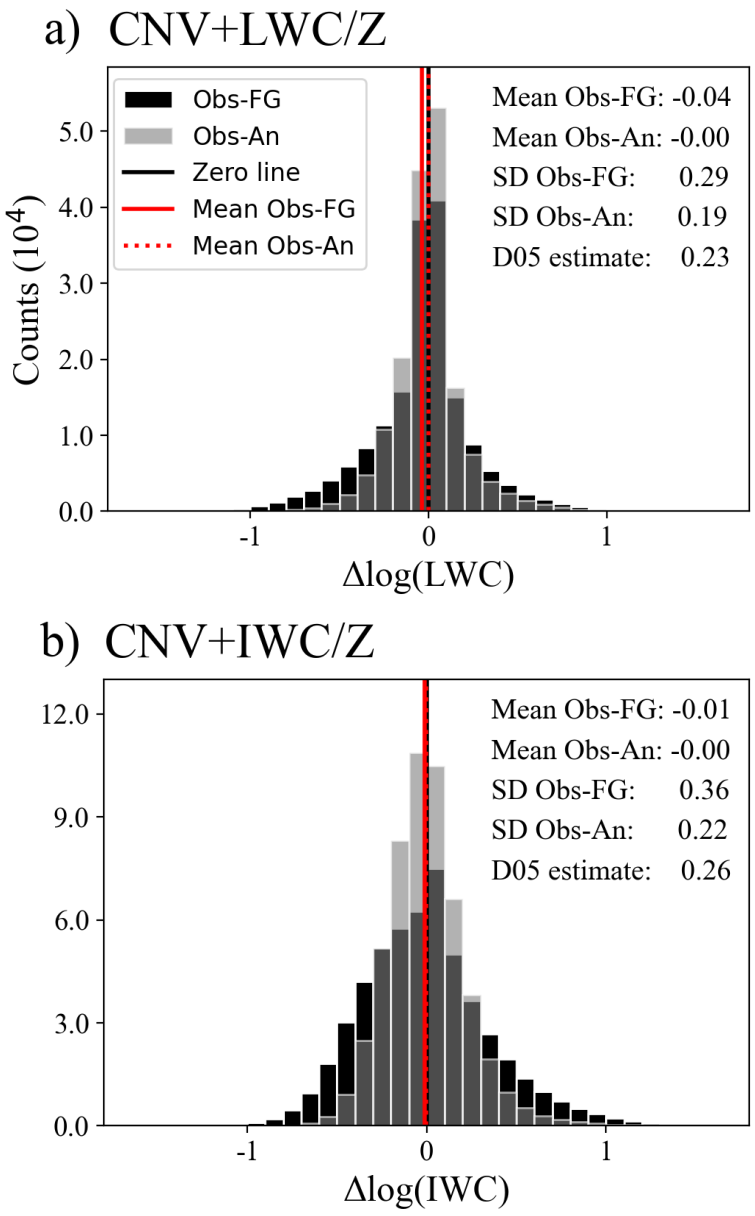
- Assimilation of LWC mostly improves first-guess QPFs w.r.t. CNV+Z configuration
- Assimilation of IWC degrades first-guesses for the convective precipitation, but improves QPFs especially for the 2021 stratiform case
  → *Possibly because IWC retrieval unsuitable for hail/graupel in convective precipitation and KDP estimation for 2021 improved due to increased radial resolution*
- Best first guesses when all radar data sets (LWC, IWC, Z) are assimilated together in the CNV+LWC+IWC+Z configuration

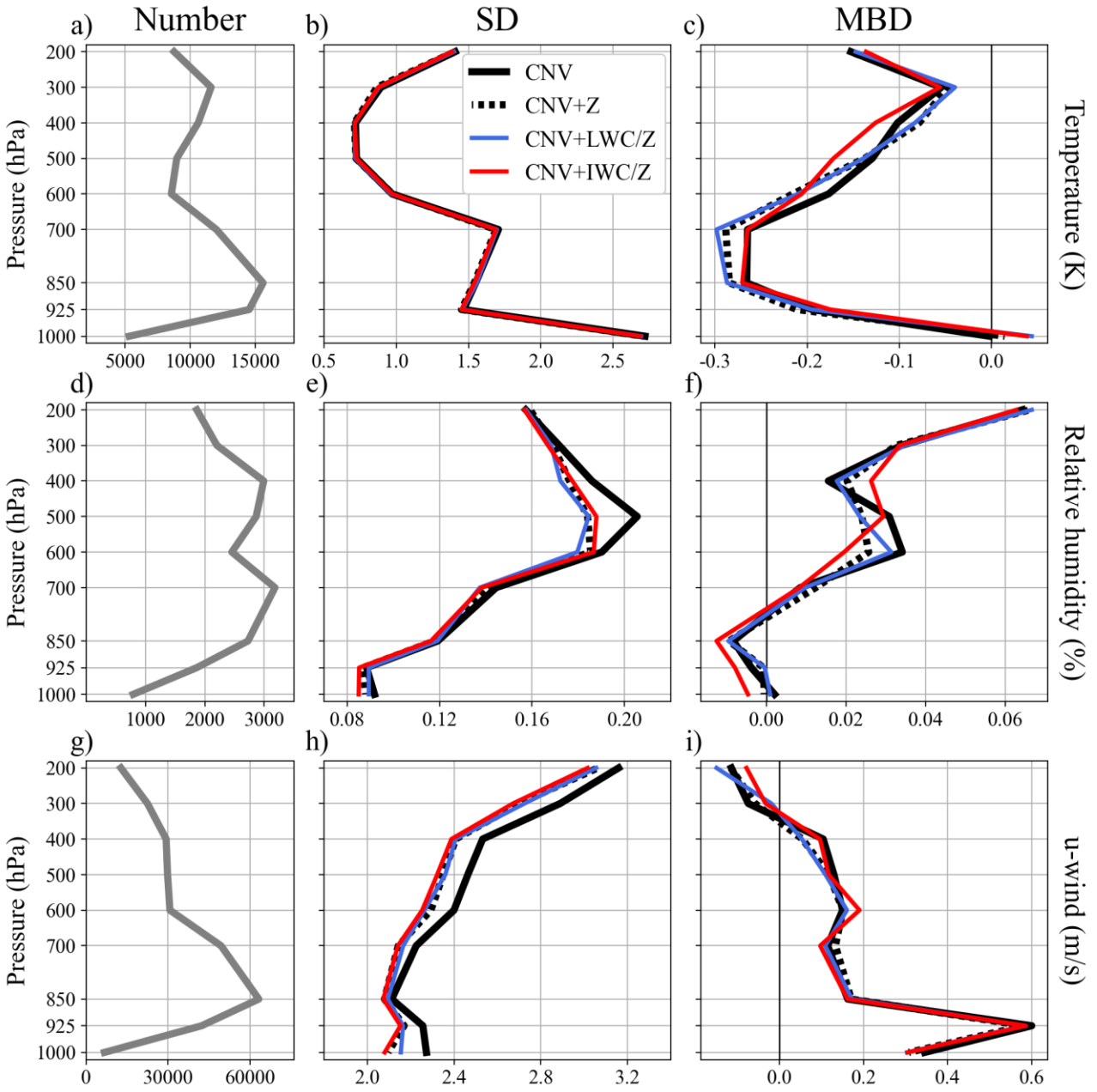
Nine-hours forecasts

- LWC assimilation in CNV+LWC/Z improves nine-hours QPFs over CNV+Z configuration, especially for the convective precipitation
- IWC assimilation in CNV+IWC/Z improves nine-hours det. QPFs for the stratiform cases, especially for the 2021 case, but degrades QPFs for the convective event
- CNV+LWC+IWC+Z configuration yields best nine-hours QPFs in terms of FSS over first 6 hours lead time

Appendix

Assimilation Impact on First-Guesses





Assimilation Impact on Nine-Hours Forecasts